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Circular economy and system thinking framework in design; Food system design

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By

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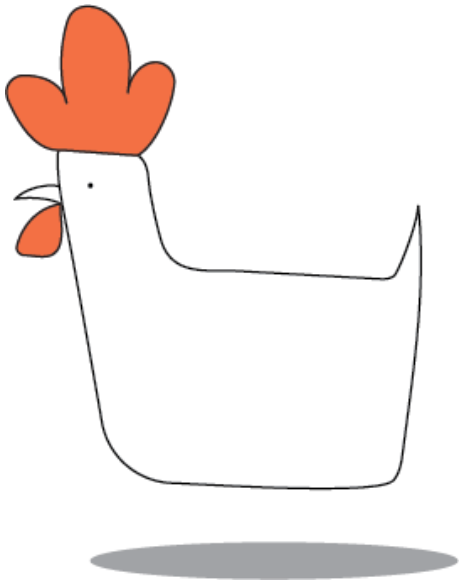

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HOW TO READ THIS THESIS?

Abstract

The purpose of this thesis is to bring the circular economy framework and system thinking into the process of design thinking. The traditional design process is made up of five steps: 1) Discover a challenge. 2) Interpret the challenge. 3) Create opportunities and ideas. 4) Develop a solution and experiment with it. 5) Evolve the idea. This project is structured upon a methodology generated to apply a circular system framework in design that begins with taking a holistic view of topic. This methodology structured into five phases. The first phase is referring to this approach as moving from Macrocosm to Microcosm; in other words, the mapping of the connections and interconnections of the system. The intersections of these cosmos create what I refer to as the main element, or the "brain" for short (Phase 1). The second phase is to deconstruct this "brain" (Phase 2) and explore the elements within it . The third phase is related with surveying. The fourth phase is defining problems based on the information I found during the past three phases. The last part is the reconstruction of the "brain" using the circular framework (Phase 5).

Phase 1:

From Macrocosm to Microcosm

Each of us must eat in order to survive. Food is one of our most fundamental biological needs. To understand what we eat, and why we decide to eat what we eat, I first examine the whole structure of food, from Macrocosm to Microcosm. I begin by examining literature on key studies of food. "From the points of view of epistemology (Theories of knowledge and method) and general zeitgeist (spirit of particular time), there have been many influences over the years on the study of food."

These are some the key studies of food:

- "Food links all major issues of geography into a spatial network influenced by physical geography, culture, society, and economics. Food is intricate to our nutrition and health as well as our agricultural practices."[1]
- Food links with culture, and social science.
- Food links with spaces of production, of preparation, and of consumption and also food generates new rules and forms boundaries within systems.
- Food links to agricultural practices and has relationships with globalization and industrialization.
- Food links with creativity, a new market, in media, and in education.
- Malnutrition and starvation in countries of the Global South have also been widely studied.

[1] Robert, D. Lemon. "Food Is Spatial: The Cultural Geography of Food,"

- Food links with agricultural economy, politics, regulations, the capitalist system, production, distribution and consumption,

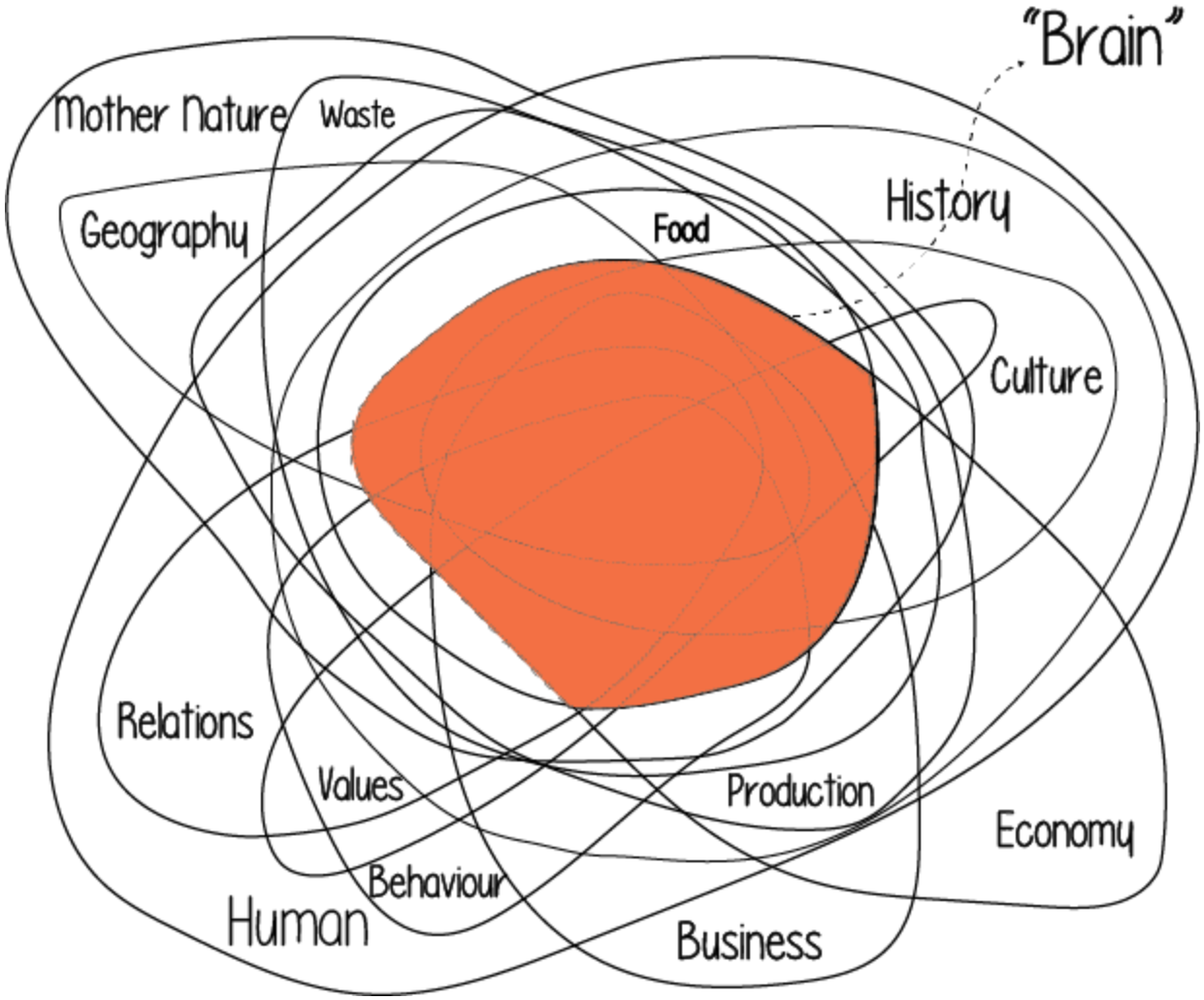


Figure A: The intersection of all these elements is creating the "Brain" of what we eat. This scheme shows that the food is much more than just survival and fuel.

Phase 2:

Deconstruction

Phase 1 shows that we are living in complex systems. If we want to understand a topic deeply, we need to see different elements and their interconnections as a whole. In phase 2, each topic is an element in food's complex system. This phase will help to shed light on the dynamics of every element within the whole picture. I begin with a defining of "system":

- A system is a group of connected elements within their own environment.
- A system addresses a function which is connected to a bigger system.
- If you remove any of these elements or change their dynamic, the system is disrupted.

Therefore, we must deconstruct the food system in order to understand it deeply.

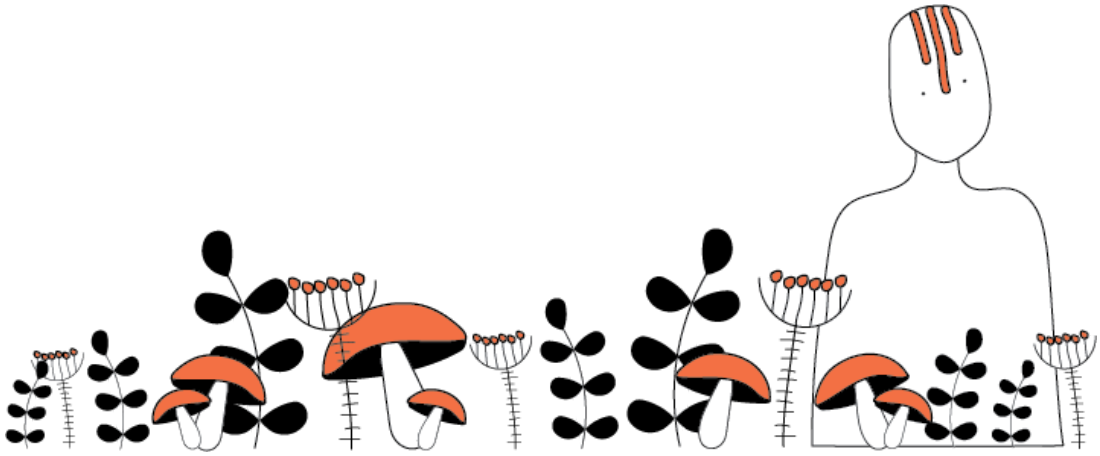
1. Historical Approach

Humans are omnivorous and can obtain food from a variety of living systems. Obtaining food was the major daily activity of early human beings. There were not enough tools and because of extreme climate conditions earlier societies used lots of energy to gather or hunt

enough food for survival. They adapted themselves to the harmony of nature and they migrated in pursuit of food sources. According to French diet developer Michael Montignac, "From the beginning and up to the Neolithic Period, approximately 10,000 years ago, man [*sic*] was a nomad who lived by hunting and picking wild fruit and vegetables and his diet was basically made up of game (protein and lipids) as well as wild berries and roots (carbohydrates with low Glycemic Indexes and high fiber content.)"[2]

In general, humans are omnivorous and nature provides a variety of living systems as food. Thus, humans have eaten what the nature has provided for them.

They have a polycultural diet.



Beginning in the Neolithic era, humans began to create settlements and use simple tools. They imposed limitations on their lifestyles and brought new rules to the environment in which they lived. The Neolithic revolution brought farming, which allowed people to produce their own food for the very first time. The new tools created to support this farming and related methods of

[2] Montignac.com by Micheal Montignac

survival changed the nutrition of humans. “Compared to the hunter-food pickers of the Mesolithic Age, the farmer-cattleman had considerably reduced the variety of the food he ate.”[3]

Early Neolithic era farming created a limited diet including grains such as wheat and millet, and meat from goats and sheep. Species varieties for planting were limited by the climate and geographical realities of particular locations. This revolution in dietary lifestyles resulted in some deficiencies which affected health and life spans.

With the industrial revolution and emergence of cities and technology, the human diet become even more catastrophic. Human migration expanded, from villages to cities and from one country to another, as people pursued new occupational opportunities and better ways of life. Migration brought the relocation of labour and skills, and other material and cultural elements.[4]

The Industrial Revolution expanded possibilities as “new farming systems created an agricultural revolution that produced larger quantities of crops to feed the increasing population.” [5] In the early 19th century, the rise of agriculture and the ownership of land in the countryside created aristocracies which had great political and economical significance. “ New tools, fertilizers and harvesting techniques were introduced, resulting in increased productivity and agricultural prosperity. Indeed, despite the phenomenon of urbanization and industrialization, agriculture remained a principal provider of employment in the provinces, both supporting and being supported by industry.”[6]

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[3] Montignac.com by Micheal Montignac

[4] I expand on the effects of migration on food culture in my sociological scale chapter.

[5] “The Industrial Revolution and the Changing Face of Britain.” *The British Museum*

[6] “The Industrial Revolution and the Changing Face of Britain.” *The British Museum*

"Enormous shifts in agricultural practices and in the manufacturing, marketing, and delivery of food occurred during the Industrial Revolution in the United States. Technological developments that made these changes possible included innovations in farming machinery, the building of railroads, improvements in refrigeration, the mechanization of food processing, and the invention of new packing materials and promotional techniques."[7]

In this millennium, the economy is driven by consumption culture. As in other industries, the linear culture (take, make, consume, throwaway) of mass production, planned obsolescence , and fast consumption, has penetrated the food market.

In the early 20th century, the food market changed parallel to changes in other commodities in the market. Processed food and fast food emerged and expanded to represent a major share of the food market, accounting for a full 70% of American's diets[8].

There are lots of reasons behind obesity, diabetes, and heart illness. Pollan writes that "We Humans are indeed omnivorous is deeply inscribed in our bodies, which natural selection has equipped to handle a remarkably wide-range diet"[9]. However, the biology of most of the food found in American supermarkets includes only a tiny range of species of plants, particularly corn and soybeans. This situation has been encouraged by the government. "For the past 50 years, U.S. farm policy has been increasingly directed toward driving down the price of farm commodities, including corn and soybeans."[10] Current farm policy concerning the low costs of corn and soybean production, make these plants two of the favorite food substances for companies and directs the food companies to explore different ways to use these additives.

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[7] "Big Business: Food Production, Processing & Distribution in the North 1850-1900,"
[8] Kai, Ryssdal. "Processed Foods," March 28, 2013.
[9] Omnivore's Dilemma, Pollan. M. p:289
[10] Food Without thought, Schoonover H. and Muller M.

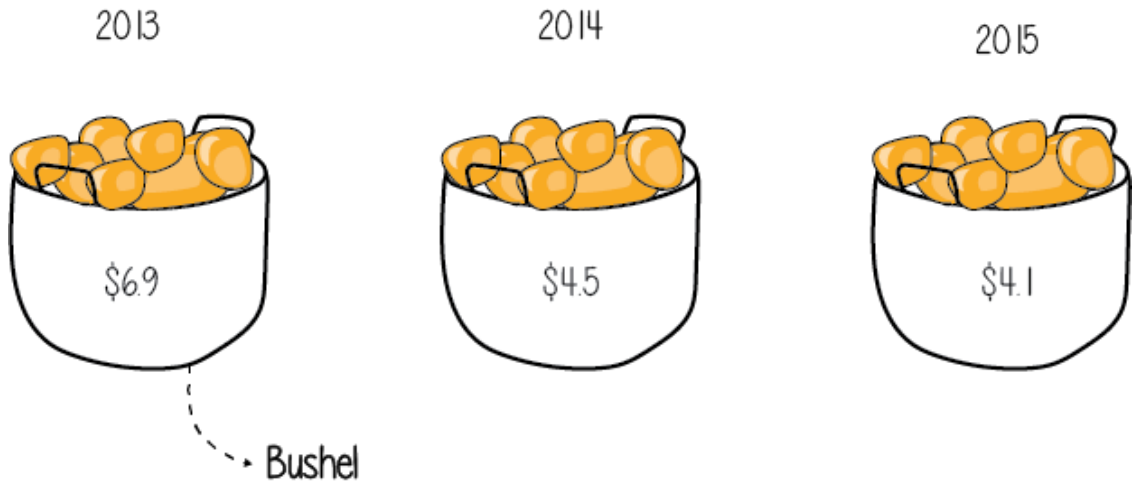


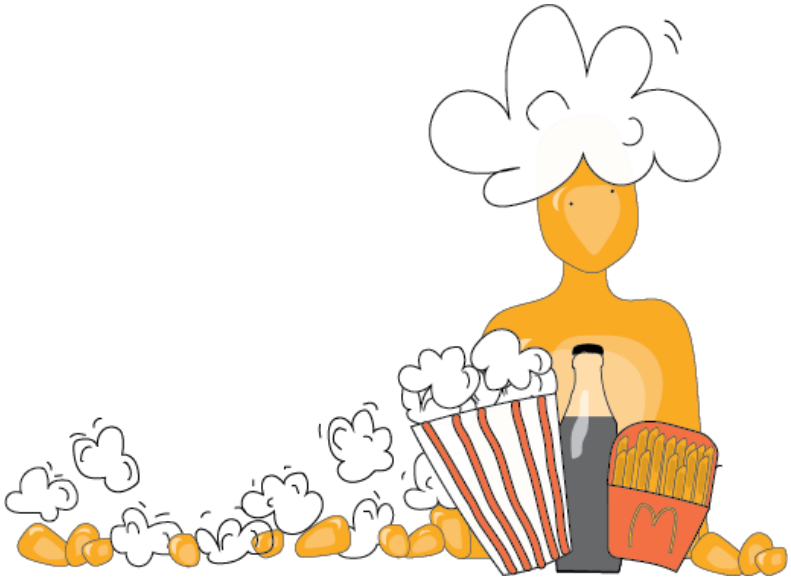
Figure B: The price of corn in last three years (https://ycharts.com/indicators/corn_price)

Corn and soybeans are two miracle substances in that they did not exist just a couple generation ago. Today, they dominate in the entire food system. “Corn feeds the chicken and pig, the turkey and the lamb, the catfish and the tilapia and, increasingly, even the salmon”[11].

According to Todd Dawson, a plant biologist at the University of California-Berkeley, "We are what we eat with respect to carbon, for sure. So if we eat a particular kind of food, and it has a particular kind of carbon in it, that's recorded in us, in our tissues, in our hair, in our fingernails, in the muscles."[12] Corn maintains its identity. If you take one of your cells and examine it in the lab, you can see what percentage of your cells are made of corn.

[11] Omnivore’s Dilemma, Pollan. M. p:18
[12] Sanjay, Gupta. “If We Are What We Eat, Americans Are Corn and Soy.” *CNN*,

The wrong policies of farming, the high prices of quality soil and fertilizers, and the regulations in the international market, all contribute to limitations in human diets in this millennium. These factors have lead to our diets becoming monoculture.



2. Food; Global-Geopolitical scale

'Diverse policy instruments relate closely to "food policy" in the wider sense, affecting nutrition, longevity, etc., going well beyond the production of food. The "food problem" should be seen in these wider terms, involving not only the production of food, but also the entitlements to food and to other nutrition-related variables such as health services.'[13]

- Marnie J. McCuen

A. Agriculture

Farm policy in the United States has changed over time to accommodate a growing population. Farming has transferred from a family-scale institution to an industrial-scale, which

[13] McCuen, Marnie J. *Famine & Fat, p: 8.*

initially required a huge labor force. Changes in farming technology, the prices of crops, common farming methods, and increases in the speed of farming all affected the key ingredient in farming: soil.

"Soil is the skin of the earth. It's the first point of contact between the planet and the atmosphere. The highly fertile top layer of soil - the uppermost twenty centimeters or so - is known as topsoil. Like the air we breathe, this layers of earth is so ordinary and ever-present that it is easy to take for granted. But it is absolutely essential to our lives, health, and prosperity."[14] Human beings extract advantages from nearly every layer of the earth. They use the outermost layer of soil not only for agriculture, but also as what McDonough and Braungart describe in *Cradle to Cradle* as "away," meaning a place to hide their waste from industry, mass production, and consumption culture. When new industries and technologies emerged to address the growing population's need for more food, new practices were introduced to the agricultural industries just as they were in other industries. All of these processes were linear and, until just a few short decades ago, human beings wrongly believed that the earth' resources were limitless.

"By maintaining larger and larger farms, using giant machinery that tills the topsoil and kills all but planned-for crops, planting giant monocultures (identical crops), and soaking the land in pesticides, weed killers, and chemical fertilizer, industrial agriculture strip-mines the soil. A cultivated topsoil is scoured away by rain, or blown away by wind, what remains is less fertile. What's more, the steady chemical beating topsoil across the United State has taken over

[14] Steffen, Alex. 2006. *Worldchanging: A user's guide for the 21st century*. New York: Abrams.

the last fifty years has killed off many of the microorganisms that keep soil alive. Dead soil no longer soil: it is just wet dust."[15]

All of these chemical treatments have decimated our soil. Furthermore, these chemicals in the soil are washed out by rain, where they flow into rivers, lakes, and oceans, and pejoratively affect the safety of seafood as well.

B. Population

The relationship between the increasing rate of population growth and the ability to sustain this population with adequate food production is one of the most important and controversial global dilemmas. According to the United Nations Fund for Population Activity, it was estimated that 1999 marked the world's 'Overpopulation' year, when the total population of earth reached 6 billion people.

In the 1990s, with the population growing fast, the concept of "cheap food" ended. Chemical fertilizers were replaced with organic ones and new farm policies were created. The earth's resources had been used in unsustainable ways and, for the first time, the fragility of food systems and food security related to population growth emerged.

The lack of food and the alarming state of the earth's natural resources pointed to the acceleration of global population growth. Moreover, the uneven geographical distribution of population growth often revealed that many places with high rates were also facing great economic disadvantages and were ill-equipped to deal with expanding hunger. 'The developed countries have ageing populations and have reduced their fertility to replacement levels only, the

[15] Steffen, Alex. 2006. *Worldchanging: A user's guide for the 21st century*. New York: Abrams.

poor nations have yet to complete this "demographic transition" and in consequence their growth potential over the next few decades remains high.'[16]

In conclusion, the rapid growth of the world's population and the corresponding increasing demand for food began to reach a crisis state in the 1990s creates:

1. Intensive use of natural resources
2. Global warming, "shifting weather pattern and the flooding of fertile coastal land by raising sea level."[17]
3. "250 million people have died from hunger-related cause since 1970" [18]

With the emergence of a rapidly growing population, "Food production has tripled since 1945 and average food availability per person has risen by 40 percent."[19]This overproduction of cheap food resulted in a increased food waste in most countries of the Global North, including the USA. "In the USA, 30-40% of the food supply is wasted, equaling more than 20 pounds of food per person per month."[20] Such wasteful habits have devastating environmental effects. According to Georgia Griffin, all of this food waste is sent to landfills, where it then annually generates greenhouse gases equal to that produced by two million cars.[21] I discuss food waste in greater detail in the next chapter.

C. Malnutrition

'"Undernutrition" is usually defined as an inadequate intake of calories and "malnutrition" as an imbalance of nutrient consumption, usually due to a shortage of a key

[16] Peter, Atkins, and Bowler Ian. *Food in Society*, p:109.
[17] Peter, Atkins, and Bowler Ian. *Food in Society*, p:109.
[18] Peter, Atkins, and Bowler Ian. *Food in Society*, p:109.
[19] Erwin, Northoff. "Healthy and Sustainable Food Systems Are Crucial to Fight Hunger and Malnutrition." *Food and Agriculture Organization of United Nation*, January 17, 2014.
[20] United Nations Environment Programme, Regional Office of North America
[21] Georgia, Griffin. "Leftovers--Into the Trash or Kitchen Disposal? Essential Answer,"

vitamins and minerals. Occasionally problems may arise where the soil is deficient in certain elements due to geological factors. It is possible to be malnourished even in rich countries, for instance on an unbalanced diet of junk food, or through over-eating, leading to obesity.'[22]

Along with changes in the speed of food production, agricultural practices also changed. As stated earlier, many foods were replaced with cheaper and/or faster growing foods. The cattle industry developed to accelerate the growth of cows for both meat and dairy. Similar developments increased the rates at which plants were grown and harvested. This process involved the manipulation of food's DNA, to maximize speed of growth. This created abnormalities in foods, with some processed foods in the market creating diseases.

It is estimated that the diets of 70% of American people are based on these processed foods, with a full 85% of Americans unable to afford fresh fruits and vegetables.[23] This reality helps explain "where man [*sic*] lost his way and ended up on a path to obesity, diabetes and heart illness."[24] This problem is not limited to those in the United States. As Erwin states, a full "1.5 billion people are overweight or obese, consuming more food than their bodies need and exposing them to greater risk of diabetes, heart problems and other diseases."[25]

The problem is nevertheless acute in this country, as "Four of the top ten killers in America are chronic diseases linked to this diet."[26] Changing this situation is difficult considering that there is a massive economy based on this linear-produced dietary system. Processed food (cheap and low quality ingredients) has a high profit yield and "the healthcare

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[22] Peter, Atkins, and Bowler Ian. *Food in Society*, p:125.

[23] Latetia, V. Moore, and E. Thompson Frances. "Adults Meeting Fruit and Vegetable Intake Recommendations — United States, 2013,"

[24] Montignac.com by Micheal Montignac

[25] Erwin, Northoff. "Healthy and Sustainable Food Systems Are Crucial to Fight Hunger and Malnutrition." *Food and Agriculture Organization of United Nation*, January 17, 2014.

[26] Michael, Pollan. *Food Rules an Eater's Manual*. P: xii

industry makes more money treating chronic diseases (which account for three quarters of $2 trillion plus we spend each year on healthcare in this country) than preventing them."[27]

According to the Food and Agriculture Organization, 840 million people suffer from hunger every day. This malnutrition and hunger affects their ability to work, to progress, to achieve adequate physical development, and it creates illnesses and sometimes leads to early death. "Hunger is more than just a temporary physical discomfort, the most that is ever normally experienced in the nutritionally comfortable developed countries. It is often a chronic (recurring and long-term) and severe condition that may be a precursor to famine and starvation."[28] This state of affairs becomes even more frustrating when we consider that "The world produces enough food to feed every man, woman and child on earth. Hunger and malnutrition therefore are not due to lack of food alone, but are also the consequences of poverty, inequality and misplaced priorities."[29]

D. Famine

Famine can be defined as an "extreme and general scarcity of food."[30] Famine is a socio-economic phenomenon which affects people, or a subsection of people, on a widespread scale. Aykroyd writes that "The most important natural cause of famine has been drought due to insufficient rainfall, preventing crops from being sown and harvested, and killing off domestic animals."[31] Famine may also be caused by floods, which destroy crops, and war, which prevents farmers from being able to safely complete their work.

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[27] Michael, Pollan. *Food Rules an Eater's Manual*. P: xiv
[28] Peter, Atkins, and Bowler Ian. *Food in Society*, p:130.
[29] UNICEF Deputy Executive Director, Kul C. Gautam
[30] *The Oxford English Dictionary.*
[31] Aykroyd, W. R. 1975. *The conquest of famine*. New York: Reader's Digest Press : distributed by E. P. Dutton.

In short, every aspect of food is interconnected, from its production to its consumption, and from natural disasters, to anthropogenic forces, including technological changes in the agricultural industry. Global climate change, which has also been affected by human behavior, plays a role as well.

3. Food; Cultural-sociological scale

Food is more than just what we eat every day. It is a complicated matter. Our biological structure has nutritional needs. We have cultural practices and social meanings inscribed on our food. There are political issues based on food in all geographical settings. We have values about food based on our religions, histories, and personal backgrounds. We have a complicated relationship with food and all of these various elements "create desirable or undesirable food and drink"[32] for us.

By the late 2000s, food, drink and cuisine studies had become scholarly pursuits, with multidisciplinary research on these subjects ranging widely (in fields such as Anthropology, History, Biology, Economics, and Political Science). Food as a tangible object has occupied a space. It both exists and subsists, and is at the same time accessible to both our senses and our thinking processes. When we become hungry or thirsty we desire food based on our emotions and on our cognitive values.

Roland Barthes discusses the complexity of food as an object of inquiry in *Contemporary Food Consumption.* He states that "It is not only a collection of products that can be used for statistical or nutritional studies. It is also, and at the same time, a system of communication, a body of images, a protocol of usages, situations, and behavior."[33]

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[32] Carolyn, de la Pena, and Lawrance Benjamin. "Food Ways, Foodism or Food Scares? Navigating the Local/global and Food/culture Divides," n.d.,P:2

[33] Roland, Barthes. *Contemporary Food Consumption*, p:29

Food is a tangible object. Food occupies a space in its living system during its production, its harvest, its preparation, and its consumption. Food requires time for all of these processes. Different climates and geographies create different types of food. Different soils give food different chemical compositions. Food has vitamins, calories, proteins, and minerals. Food has colors, smells, and textures. Through human manipulation, food takes different forms. "A Food is something that can be eaten. It may be a basic food such as salt or it may be the more complex result of another recipe, for example chicken stock. A recipe uses foods as part of ingredients and also produces foods to be eaten."[34]

All living systems must eat to survive. Capaldi writes that "Eating is both necessary for life and a source of considerable pleasure."[35] Human eating behavior is shaped by both innate mechanisms, as well as by cultural, social, religious, and other experiences (learned behaviors).

"Innate preferences may be expressed for simple taste at birth; however, in omnivores the process of developing food preferences occurs in stages over time, exploiting the ability to pair certain tastes, smells, flavors, and food with postingestive consequences. For example, newborn infants respond positively to the taste of sweet solutions and reject sour and bitter solutions" (Steiner, 1977).[36] These innate preferences create emotional relationships with our food.

There "are real manifestations of the way that emotions control our muscle systems and yes, even our digestive system. Thus, pleasant tastes and smells cause you to salivate, to inhale and ingest. Unpleasant things cause the muscles to tense as preparation for a response. A bad taste causes the mouth to pucker, food to be spit out, the stomach muscles to contract. All of

[34] "Food Ontology." *BBC Ontologies*
[35] Capaldi, Elizabeth. *Why We Eat What We Eat The Psychology of Eating*, p:267
[36] Elizabeth, Capaldi. *Why We Eat What We Eat The Psychology of Eating*, p:267

these reactions are part of the experience of emotion."[37] Emotional relationships are not only innate, sometimes they are created by experiences and values during our lifetimes. The pleasure of food is learned and is deeply rooted in our experiences and backgrounds (historical, cultural, and social). These experiences have a tight relationship with the emotional systems of the human body, and they affect behavior and generate human responses.

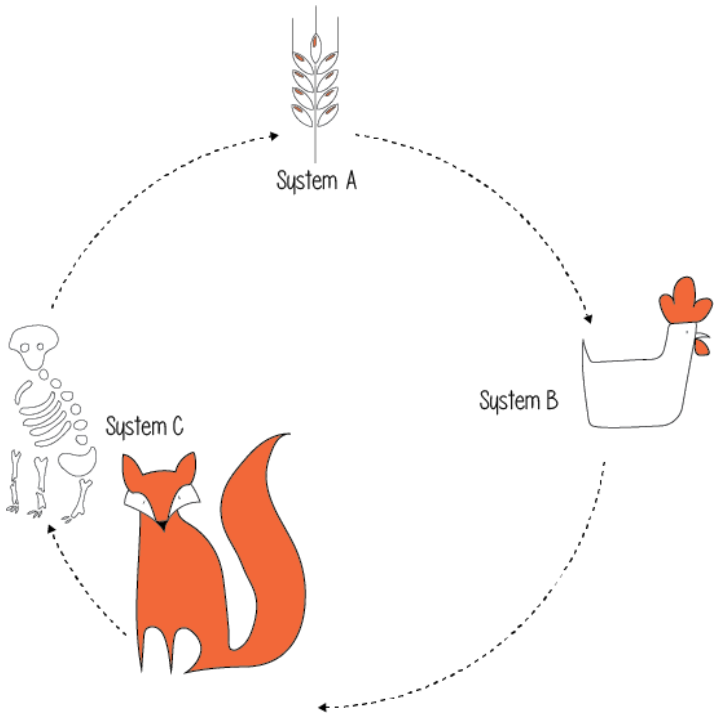
According to food designer Marije Vogelzang, eating food "is social glue, a showcase of our identity that can comfort us, reveal memories of forgotten times and hidden places. Food can bring joy, status, sadness, conviviality and connection."[38] Food is a major element of who we are as people.

4. Food; Business and economy systems

A. Nature system vs. human made system

Living systems are self-organized elements that have worked and interacted together and within their environments for more than a billion years. There is no waste in living systems. All systems are connected with one another. In the illustration below, System A extracts energy from the sun and soil, and then provides food and energy for System B. System B is consumed by system C. When system C reaches the end of its life cycle, it is decomposed and returns to the soil to become nutrition which helps sustain System A. This schema shows a simplified version of how the living system works circularly:

[37] Donald, Norman. *Emotional Design*, p:12
[38] *Food Player*. Gingko Press, p:004



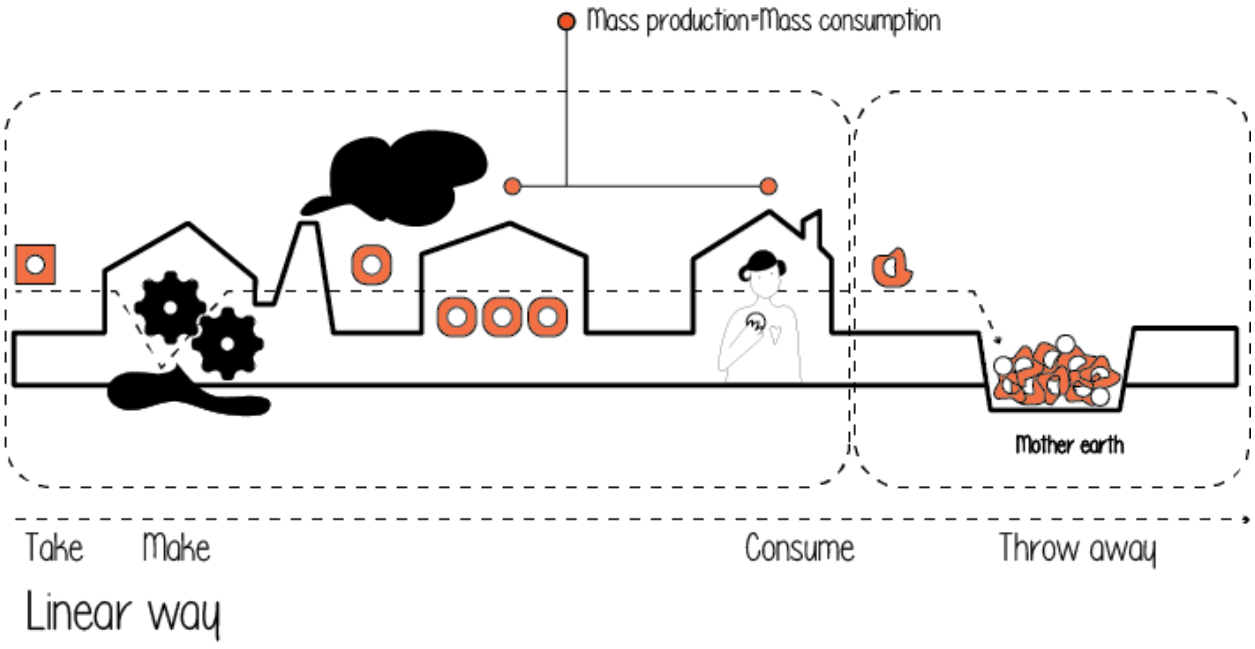
Historically, the food of humans worked in a circular way as well, with all food produced and consumed locally.

With the world's growing population and advances in technology, the historical era of (small scale) food production ended, and humans constructed new systems for food production and distribution. Globalization and economic forces on a worldwide scale have encouraged a throwaway culture as part of a capitalist model.

Throwaway culture penetrates the market, which "has characterised and underpinned industrial economies for more than half of century."[39] Humans take, make, and dispose of materials, which is a linear process. This system poisons the air, soil, and water; generates waste, including dangerous materials; and consumes natural resources at a faster rate than they can be

[39] Bakker C,Hollander Marcel, Hinte E., Products that last, p: 5.

renewed at. Researchers, governments, and societies must respond by creating alternatives to this linear system.



At the dawn of the industrial revolution, there was no anticipation of the eventual consequences of rapid mass production. Nature was described as '"Mother earth" who, perpetually regenerative, would absorb all things and continue to grow.' [40] Fordism and the acceleration mass production have exacerbated the pejorative environmental effects.

After observing the results of a long period of quick linear system, our understanding about nature has changed. The air, the water, plants and soil are vulnerable and are not renewable and '"Away" has gone away'[41]

[40] W. McDonough & M. Braungart, *Cradle to Cradle*, p: 25
[41] W. McDonough & M. Braungart, *Cradle to Cradle*, p: 25

B. Waste in human made system

- **Waste management**

Different from living systems in nature, human-generated waste (Solid waste, sewage, biodegradable waste) uses more natural resources and wastes them again. Significantly, since the dawn of our throwaway culture and exacerbated by the growth of populations in cities, the expanding generation of waste could no longer be ignored. The ever-increasing accumulation of waste necessitated its management and the emergence of landfills.

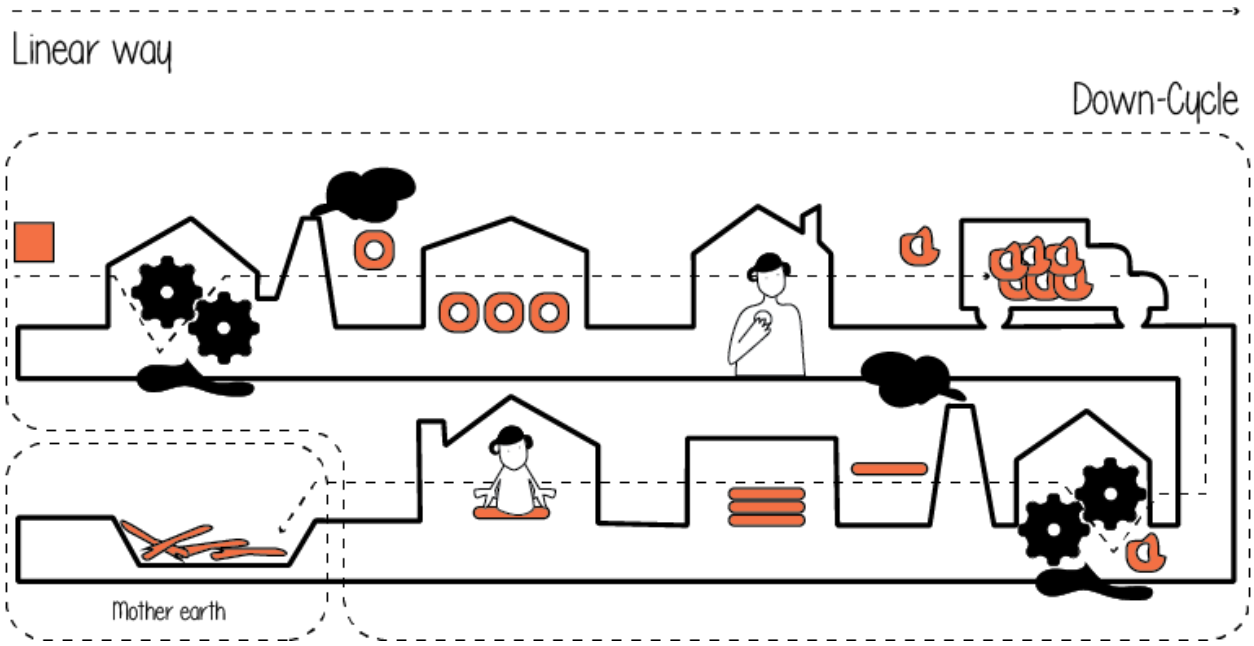
In an attempt to reduce the impact of landfills and to improve the waste industry and protect human health, recycling has become a highly developed technology. Recycling is the process which reduces the consumption of fresh materials and can be dichotomized between downcycling and upcycling.

1. Downcycling

McDonough & M. Braungart state that "Most recycling is actually downcycling; it reduces the quality of a material over time."[42] Most of the plastic and metals that are often downcycled, for example parts of a steel car, are recycled along with other metals, paints, and other materials, which create a low-quality metal. "Lost value and lost material are not the only concerns. Downcycling can actually increase contamination of the biosphere. The paints and plastics that are melted into recycled steel, for example, contain harmful chemicals."[43] Furthermore, downcycling "can be more expensive for businesses, partly because it tries to force

[42] W. McDonough & M. Braungart, *Cradle to Cradle,* p: 56
[43] W. McDonough & M. Braungart, *Cradle to Cradle,* p: 56

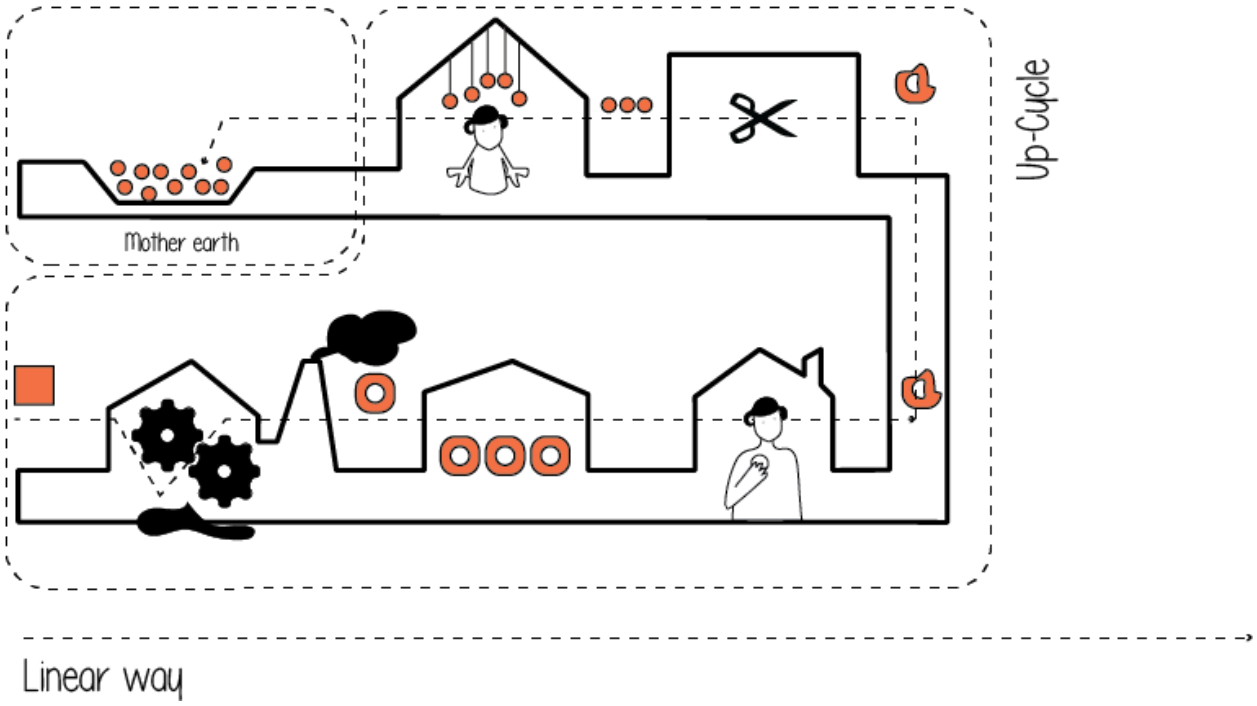
materials into more lifetimes than they were originally designed for, a complicated and messy conversation and one that itself expends energy and resources."[44]



2. Upcycling

According to William McDonough and Michael Braungart, upcycling focuses more on leaving a positive material and energy footprint for future generations. Upcycling does not reduce the quality of the material; rather, the whole product changes its function and becomes another useful product. The lifecycle of the material is therefore optimized. However, as with any other linear system, when the functionality of the product ends, it ends up in a landfill. Even natural, biodegradable materials create a large amount of waste, and generate lots of greenhouse gases and lots of energy waste.

[44] W. McDonough & M. Braungart, *Cradle to Cradle*, p: 59



3. Biodegradable material

Biodegradable materials, such as paper, food leftovers, cotton, and wood, are part of the living system and are natural resources. These materials, unlike of human-made synthetic materials, can breakdown in nature. This does not mean that paper or any other biodegradable materials should be replaced with other human-made and toxic materials.

Paper:

With the development of computerized technologies, people have started to consider a paperless life, but still huge amounts of paper are wasted in the world. Although paper is a biodegradable material, it is not a zero-waste material. Producing paper means cutting trees, using energy processes and lots of chemicals. It is estimated that "42% of all global wood harvest is used to make paper"[45], a staggering amount.

[45] "Paper Comes from Trees…." *The World Counts*, n.d.

"Facts about Paper and Paper Waste

- As we speak, more than 199 tons of paper has already been produced.
- 324 liters of water is used to make 1 kilogram of paper.
- 10 liters of water is needed to make one piece of A4 paper.
- 93% of paper comes from trees.
- 50% of the waste of businesses is composed of paper.
- To print a Sunday edition of the New York Times requires 75,000 trees!
- Recycling 1 ton of paper saves around 682.5 gallons of oil, 26,500 liters of water and 17 trees.
- Packaging makes up 1/3 or more of our trash.
- U.S offices use 12.1 trillion sheets of paper a year.
- Paper accounts for 25% of landfill waste and 33% of municipal waste.
- With all the paper we waste each year, we can build a 12 foot high wall of paper from New York to California!
- Lessening of paper usage was predicted due to the electronic revolution. It didn't happen. Demand for paper is expected to double before 2030.
- Every tree produces enough oxygen for 3 people to breathe."[46]

Although outside the scope of this project, further research is needed to learn more about how the paper-producing industry utilizes child and slave labor, serious human costs on top of the already high cost of environmental damage that the industry creates.

Corn plastic:

[46] Paper Comes from Trees…." *The World Counts*, n.d.

One contemporary biodegradable material is corn plastic, which is also know as Polylactic Acid or PLA. Many companies have started to replace with this plastic to use in the production of plastic bags, cold single-use cups and so on.

Corn plastic is made of genetically modified corn. To grow this corn, there is the need to use lots of petroleum-based fertilizers in soil. So, although the resulting product is biodegradable, the production of this material ruins the soil and relies on fossil fuel sources.

C. Current linear business models

Business models are linear in that they are product and money-oriented. Under these models, food has been commoditized similarly to other mass-produced goods. Money is the big concern in business models of linear systems. The dominant strategy between companies in linear systems is competing to grab greater shares of existing demand in the market. Every output in a linear system is commoditized and it makes the business strategy in this system product-oriented, based on existing demand. There are millions of products out there in market to answer the single demand and the price of each commodity becomes the main value of the system. So as a result of this, companies need to compete with each other related with price, but, as material and energy sources are expensive, they often need to reduce the quality of their commodities. Reducing the quality of commodities means reducing their life cycles and accelerating the production of new, cheap, low-quality commodities.

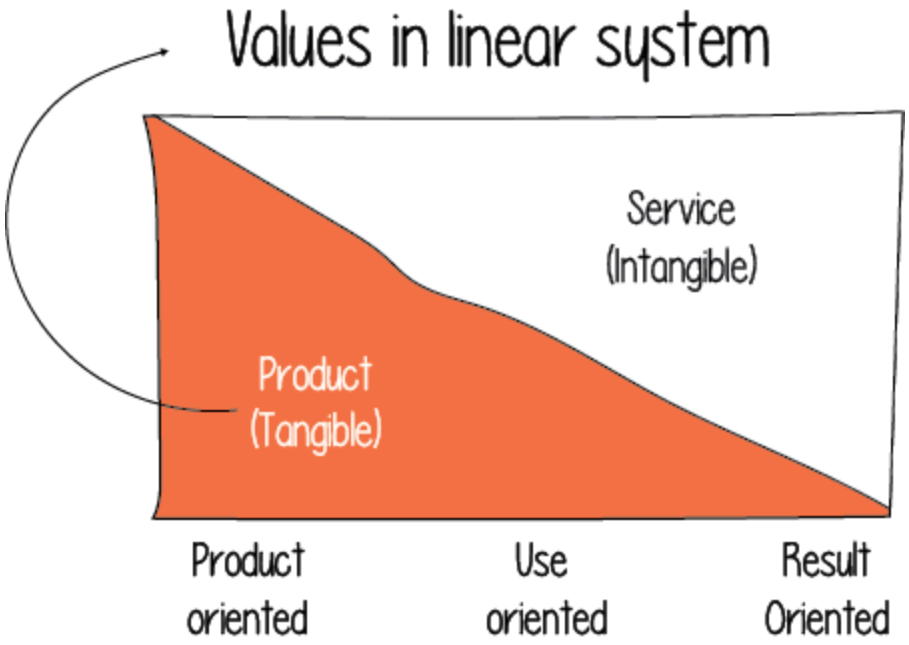


Figure C: Values in linear system (Source: Delft University, Circular Economy online course)

This old business model (take, make, sell, consume, waste) is unsustainable. It depletes our natural resources. Mother nature cannot sustain this amount of waste indefinitely.

Companies with linear system business models:

1. McDonald's

The McDonald's brand has become one of the most well-known and largest companies globally since 1940. Royle writes that "It is the largest food service operation in the world in terms of system-wide sales. At the befinning [*sic*] of 2000 it was operating more than 25,000 restaurants in 116 countries."[47] McDonald's introduced the concept of a fast food chain to the food industry. Fast food revolutionized the food industry, drastically changing food and

[47] Royle, Tony. *Working for McDonald's in Europe*, p:16

distribution businesses. The cheap price of the company's food, its speedy service, its accessibility, and its widespread reach changed human eating behaviours. Fast consumption culture began to penetrate the food industry. It has significantly changed food culture on a global scale in a short time.

2. Walmart

Walmart is a great example of a linear system business plan. Walmart is among the top ten most financially successful businesses in the USA. Lutz writes that "Walmart has been able to make huge profits by keeping worker wages low and using its size to negotiate cheaper prices than competitors."[48]

Phase 3:

The use of a survey to collect information and deeper insights was necessary for this project. I needed to create a systematic survey to include the practices, knowledges, cultures, and values of human beings into my research. Creating this survey helped me to shift my perspective from my own biases, to empathize with others, and look and my research topics from their points of view. Being an international student was advantageous to me for this process as it helped me to ask and understand different perspectives from different cultures and languages.

Survey

For my survey, I asked eighteen questions related to the problems I defined during the constructing phase. I shared this survey through social media. Sharing a food survey on a virtual media reminded me of a famous and popular game: Farmville. I asked myself, what is it that

[48] Lutz, Ashley. "Walmart's Entire Business Model Is Crumbling." *Business Insider*, October 38, 2015.

people love about this game? This game was directly related to my topic: food. I decided to add some more questions to my survey related to the virtuality of food in this game. One hundred anonymous participants took part in this survey. The participants represented a variety of different cultures, ages, and backgrounds. My survey methodology was both quantitative and qualitative.

1. How would you rate your health?

Answer Choices	Responses	
Healthy	62.37%	58
Average	34.41%	32
Unhealthy	3.23%	3
Total		93

2. Which best describes where you live?

Answer Choices	Responses	
Urban	70.21%	66
Suburban	22.34%	21
Rural	7.45%	7
Total		94

3. Which type of housing do you live in?

Answer Choices	Responses	
Apartment	78.26%	72
House	16.30%	15
Rural house	1.09%	1
Suburban house	4.35%	4
Total		92

4. How long is the journey from your home to your primary source of food?

Answer Choices	Responses	
1-10 minutes	75.53%	71
11-20 minutes	18.09%	17
21-30 minutes	4.26%	4
More than 30 minutes	2.13%	2
Total		94

5. What form(s) transportation do you use for doing your grocery shopping? (select all that apply)

Answer Choices	Responses	
Car	63.83%	60
Walking	65.96%	62
Public transportation	21.28%	20
Online	15.96%	15
Other	3.19%	3
Total Respondents: 94		

#	Other (please specify)	Date
1	Bicycle	1/31/2016 9:01 AM
2	Motocycle	1/28/2016 2:23 PM
3	Bike	1/28/2016 5:36 AM
4	Bike	1/27/2016 10:23 PM

6. Where do you prefer to do your grocery shopping? (select all that apply)

Answer Choices	Responses	
Big box stores (Walmart, Target, Cosco, etc)	24.47%	23
Public Market	44.68%	42
Farm Market	41.49%	39
Family Market	19.15%	18
Super Market (Wegments, Tops, Migros, etc)	80.85%	76
Total Respondents: 94		

7. Why do you choose this type of store?(select all that apply)

Answer Choices	Responses	
Distance from home	77.66%	73
Environment and Interior design	15.96%	15
Price	56.38%	53
Trustworthiness	37.23%	35
One-stop shopping	44.68%	42
Healthy and organic	40.43%	38
Connection to community	18.09%	17
Wholesale	14.89%	14
Tradition/ habit	39.36%	37
Total Respondents: 94		

8. How would you describe your diet?

Answer Choices	Responses	
Omnivore	77.42%	72
Vegetarian	7.53%	7
Vegan	2.15%	2
Pescatarian	4.30%	4
Raw food	2.15%	2
Fruitarian	2.15%	2
Other	4.30%	4
Total		93

#	Other (please specify)	Date
1	Mostly vegetarian, with occasional chicken and fish	1/31/2016 3:25 PM
2	I consume meat very few, but because of our culture there is not a single restaurant serving vegan	1/28/2016 4:57 PM
3	Carefully selected, no red meet	1/28/2016 2:39 PM
4	everything	1/28/2016 1:25 PM
5	I eat a limited amount of meat	1/27/2016 1:33 PM

9. Where does your food come from?

Answer Choices	Responses	
Local organic agriculture	8.51%	8
Local agriculture	24.47%	23
Family farm	0.00%	0
Industrial agriculture	39.36%	37
I do not know	27.66%	26
Total		94

10. Do you care about knowing where your food comes from?

Answer Choices	Responses	
Yes	81.91%	77
No	18.09%	17
Total		94

11. How many times do you go grocery shopping each month?

Answer Choices	Responses	
Once	3.19%	3
Twice	17.02%	16
Every week	53.19%	50
Multiple times per week	23.40%	22
Daily	3.19%	3
Total		94

12. Which types of food do you typically consume? (Select all that apply)

Answer Choices	Responses	
Home- Fresh food	60.64%	57
Home- Processed food	12.77%	12
Home- Fresh and processed food combination	55.32%	52
Ordered from outside- Fresh food	26.60%	25
Ordered from outside- Fast food	22.34%	21
Restaurant- Fresh food	58.51%	55
Restaurant- Fast food	18.09%	17
Total Respondents: 94		

13. One day you go grocery shopping and see that the carrots below are available with exactly same price. Which carrot would you prefer to buy?

Answer Choices	Responses	
France	7.45%	7
Turkey	21.28%	20
USA	7.45%	7
Sudan	0.00%	0
China	0.00%	0
Local	63.83%	60
Total		94

14. Have you ever grown your own food?

Answer Choices	Responses	
Yes	55.32%	52
No	44.68%	42
Total		94

15. Have you ever played FarmVille?

Answer Choices	Responses	
Yes	17.02%	16
No	82.98%	78
Total		94

16. Did you enjoy gardening and farming on a virtual site?

Answer Choices	Responses	
Yes	70.37%	19
No	29.63%	8
Total		27

17. Did you enjoy planting, sharing and selling food from your virtual garden?

Answer Choices	Responses	
Yes	72.00%	18
No	28.00%	7
Total		25

18. Please share your experiences of playing FarmVille.

#	Responses	Date
1	Designing farm environment make me happy.	2/1/2016 8:32 AM
2	It was addictive! I don't know why it was that addictive, but I'm happy I was able to totally stop after two weeks	2/1/2016 6:48 AM
3	I Didn't play	1/31/2016 10:37 AM
4	Since it's virtual and time comsuming, after a long time i got bored and quit playing.	1/31/2016 3:07 AM
5	I did not play FarmVille, but a similar game called HarvestMoon. The experience is great. It is satisfying to see your garden and animals grow with your "care".	1/31/2016 1:05 AM
6	I liked it at the beginning but doing the same things over and over bored me so I stopped playing.	1/29/2016 3:08 AM
7	It was mostly fun at first but then it got a little too addictive. It was not something I did for my own pleasure after a little while but merely a race between me and my Facebook friends.	1/28/2016 7:17 PM
8	It was exciting to grow your own food.	1/28/2016 5:57 PM
9	I hate virtual shit. I would quit the test if you werent a student	1/28/2016 4:57 PM
10	didn't play	1/28/2016 1:47 PM
11	It is very hard to grown own food.. in farmVille it is not.. it is just about time management.. the game bound you to your tablet or phone.. in the same mode there are cooking reastaurant games.. they doesnot feel like you run a restaurant as famville does not make me feel as I am gardening..	1/28/2016 6:12 AM
12	Actually i was not a fan of the game. Just couple of days i played it. Even if you know it is unreal, it was a satisfaction to have a garden and grow vegetable and fruits. In real life, it is really tough to care a garden, but the game helps you feel that experience. Now i look for organic food around and it would be great to be able to grow my own "trustworthy" food on my farm.	1/27/2016 2:32 PM
13	I mainly did it when I was wasting time or procrastinating.	1/27/2016 1:33 PM
14	Got addicted for a while and liked the game	1/27/2016 12:51 PM
15	It was really interesting and I enjoyed playing it . It was attracting and took some of my time when I came back home. But I had no access to Internet to play my game for about a mounth , and it killed all my crops befor harvesting them . So I lost my farm.	1/27/2016 12:42 PM

Phase 4:

After analyzing this complex food system its related human practices, it is now time to examine the gaps in this system and the elements which create both problems and opportunities.

Problem definition

In previous chapters, I defined these problems with deconstructing the whole system:

1. Food waste creates greenhouse gases which are almost equal to the total greenhouse gasses produced by the USA and China.
2. Processed foods have a major share of the market, including a full 70% of the diets of the USA population.
3. 85% of American people cannot afford to buy fresh fruits and vegetables.
4. Four of the top ten killers are chronic diseases linked to monocultural diets.
5. Several vital resources, including soil and water, are damaged by linear production systems.

Phase 5:

Let us move on to the opportunities presented by the system.

Reconstruction

Now it is time to reconstruct the system. Reconstruction is another part of deconstruction. This Deconstruction-Reconstruction methodology helped me to eliminate the pieces that were not working properly, the waste-making pieces, and the pieces that were not eco-friendly, and to replace them with a circular system.

Heart Brain Farm

1. Circular system

There are many linear solutions available for addressing problems in waste systems, but I see advantages in reconstructing this system using a circular economy approach. I decided upon circular economy because of two main reasons:

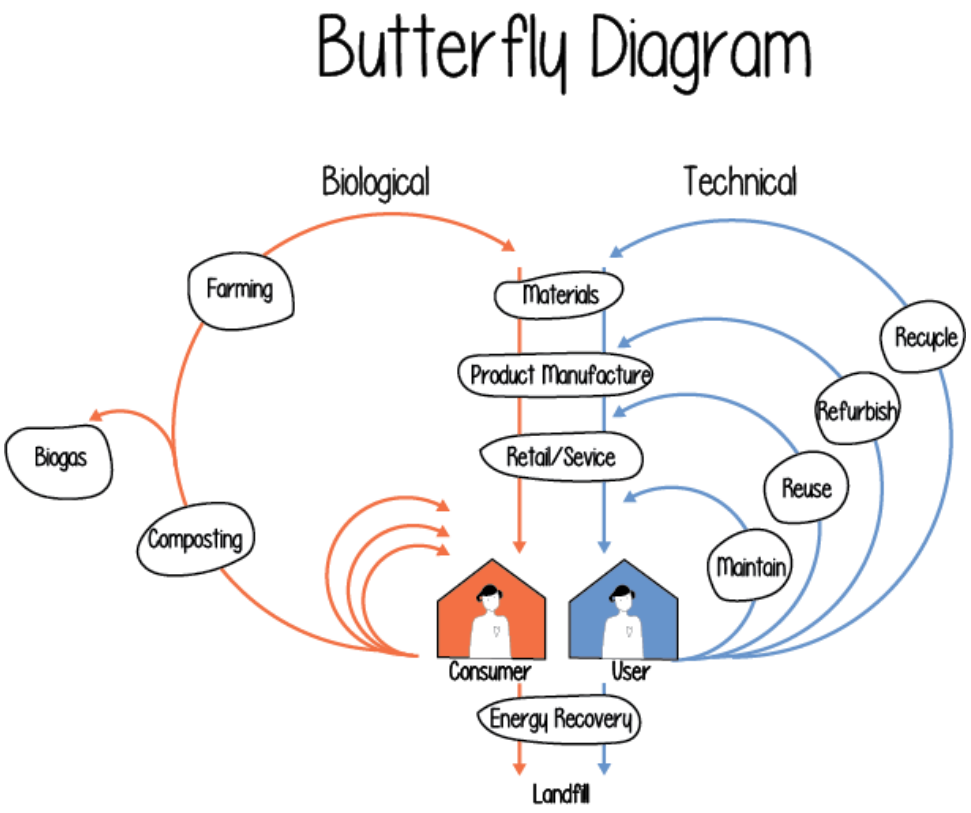
1) Circular economy maintains the values of the materials used and maximizes their life cycles.
2) Circular economy also addresses other social and environmental issues in positive ways.

According to the Ellen MacArthur Foundation, "A circular economy is one that is restorative and regenerative by design, and which aims to keep products, components and materials at their highest utility and value."[49] Linear systems have penetrated many aspect of our

[49] https://www.ellenmacarthurfoundation.org/circular-economy

lives, including our food system, water system, monetary system, our relationships with nature, and other elements of our lifestyles. These systems are not focused on maintaining sustainability. We need to instead adapt new systems which preserve every element's value to the maximum.

"A circular economy seeks to rebuild capital, whether this is financial, manufactured, human, social or natural. This ensures enhanced flows of goods and services. The system diagram illustrates the continuous flow of technical and biological materials through the 'value circle'."[50]

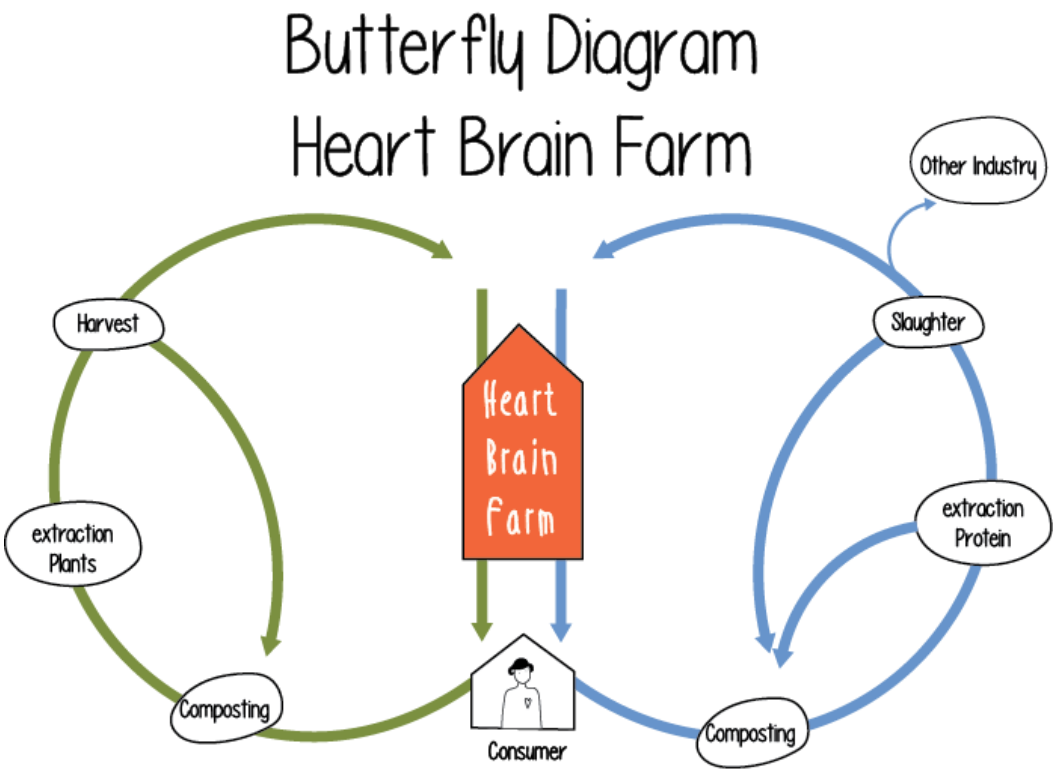


When most big institutions related to the circular economy talk about shifting from the linear economy to a circular one, they focus mainly on industry, production, and government. However, the power of individuals's daily practices cannot be ignored. The public can help by

[50] https://www.ellenmacarthurfoundation.org/circular-economy

creating demand in the market to shift from linear to circular thinking. This is the bottom-up approach.

My conceptual project, Heart Brain Farm, applies a circular economy framework to a food system. The goals are to change the daily practices of community members related with their kitchen waste and to transform the current food retail store (commodity-based) to operate on a circular pattern (community/service-based). With Heart Brain Farm, the consumer is directly involved in the production of food, and receives credits and discounts for her or his contributions to the system.



Heart Brain Farm's users collaborate with local farmers by supplying them with organic, healthy, and free resources. This eliminates the need for costly fertilizers and other products that currently render organic produce impossibly expensive for many people.

Organic fertilizers have a higher cost per unit of nutrient than synthetic fertilizer sources which, in turn, make the yielded crops' prices higher. Although seemingly-cheaper, synthetic fertilizers have long term negative effects. They kill beneficial microorganisms in soil and "Nitrogen- and phosphate-based synthetic fertilizers leach into groundwater and increase its toxicity, causing water pollution."[51]

Furthermore, most farms add hormones to animal feed, which can also create health risks for people who eat the resulting meat products. The cost of organic food for these animals makes organic protein very expensive in retail stores.

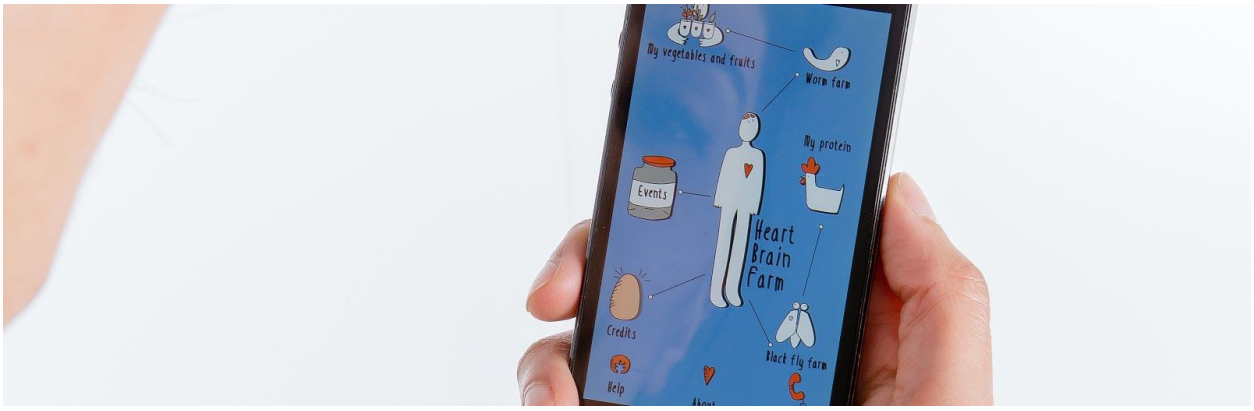
2. Heart Brain Farm User Experience

The main objective with Heart Brain Farm is the creation of a zero-waste community. In Heart Brain Farm's food retail model, users' purchases are placed in paper pulp shopping bags made from the community's paper waste. These shopping bags are then turned into garbage buckets for organic kitchen waste.

The customers dispose of any leftover food in these buckets. Users then return with their buckets to the retail stores and donate the kitchen waste to the system. Heart Brain Farm then

[51] Gilani, Natasha, and Media Demand. "The Effects of Synthetic Fertilizers,

transfers this waste based on each user's wishes, which are articulated through a convenient application. This application is modeled on the Farmville computer game, which is currently the highest rated game of its type worldwide. People enjoy planting and growing food in this virtual environment. The Heart Brain Farm system allows users to "play" with their own kitchen waste and in turn help produce real food.



Application

There are two main regenerative processes in the circular systems of the application: black flies and redworm composting. Based on her or his individual diet (black flies serve in the

production of meat products, whereas redworms are more advantageous for producing fruits, vegetables, and grains), the customer can decide on the journey of the food waste bucket.

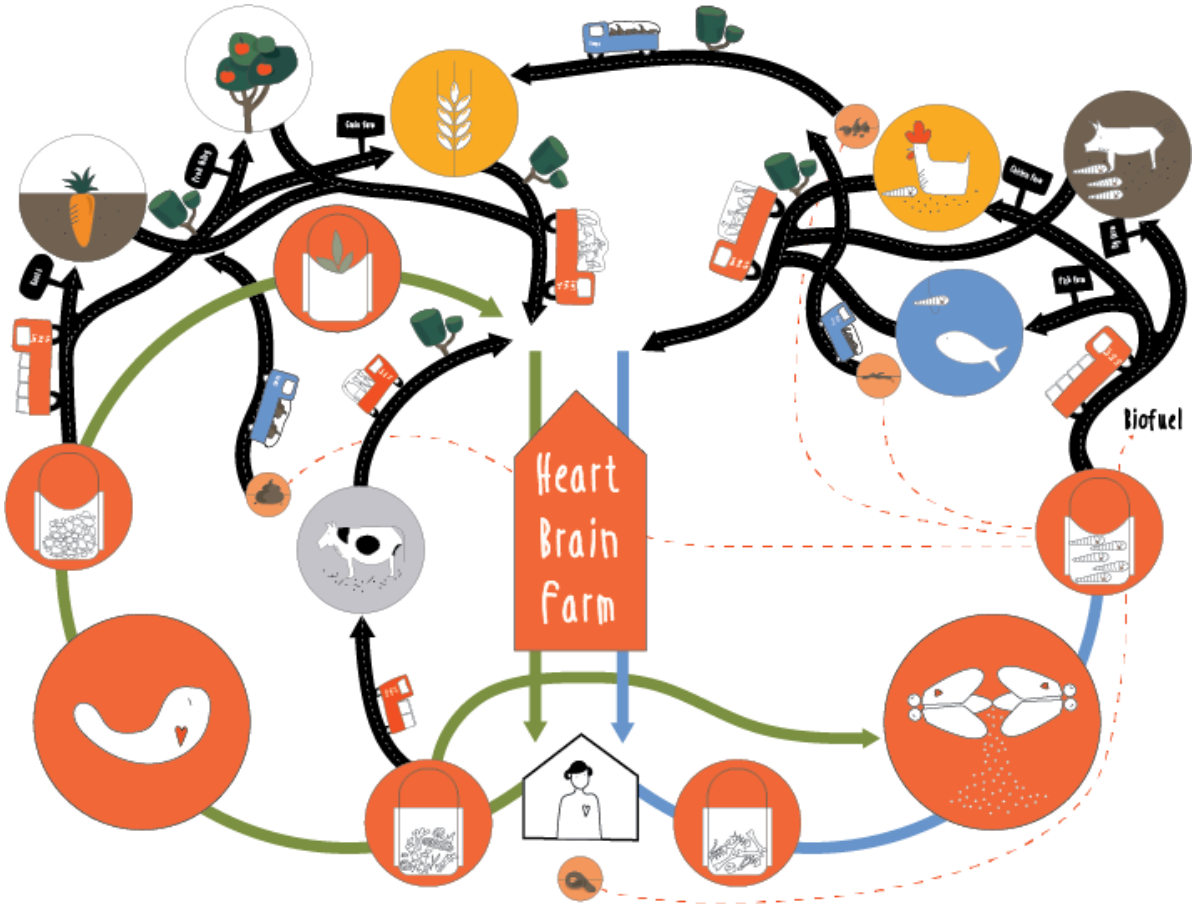
1. **Soldier Black flies** emerge, mate and die. Each time they go through this life cycle, they create 200-500 eggs in one bucket. These eggs then turn to larvae, which eat the kitchen waste and become mature. These larvae are wonderful protein sources for pigs, fish, and chickens. In the end of this circle users are awarded credit or discounts for eggs, chickens, fish, or pork products.

2. **Red worms** break down kitchen waste, transforming it to fertilizer. The fertilizer can then be transferred to local farms. In the end of this circle, users are awarded credit or discounts for vegetables, fruits, roots, or grains.

These two circles create resources for farmers, thus reducing prices on healthy food in the community. Using natural methods of transforming kitchen waste to food resources is slower than many of the technological methods applied by today's large-scale commercial farmers, but redworms and black flies duplicate easily and can therefore be conceptualized as a sustainable resource. These two living species are also highly sensitive to chemical materials. They react and die if there is chemical contamination in the bucket. This helps to ensure that the farming materials that they produce are safe and will support the growth of healthy plants.

Heart Brain Farm supports the maintenance of a healthy community while reducing the price of organic food. This, in turn, helps to reduce the costs of healthcare. Moreover, everyone

in the community would know where their food came from and because they are involved in the processes of production, the amount of wasted food would decrease.



3. Regenerative systems

Addressing problems within the circular economy does not end with keeping the material's value at a high level for a long term. The amount and type of energy used during the production or processing of the material is also important. In most composting processes, there is a huge amount of energy wasted in order to transform the waste to usable compost. To prevent this waste a regenerative system is needed.

What is Regenerative system?

"Regenerative design is a concept based on process-oriented systems theory. The word "regenerate" means "to create again." A regenerative system makes no waste; its output is equal to or greater than its input; and part or all of this output goes toward creating further output — in other words, it uses as input what in other systems would become waste."[52]

1. Blackflies System

Introduction

"Insects as food and feed emerge as an especially relevant issue in the twenty-first century due to the rising cost of animal protein, food and feed insecurity, environmental pressures, population growth and increasing demand for protein among the middle classes."[53] In most countries, these edible insects are forbidden for human consumption. "Recent high demand and consequent high prices for fishmeal/soy, together with increasing aquaculture production, is pushing new research into the development of insect protein aquaculture and poultry."[54]

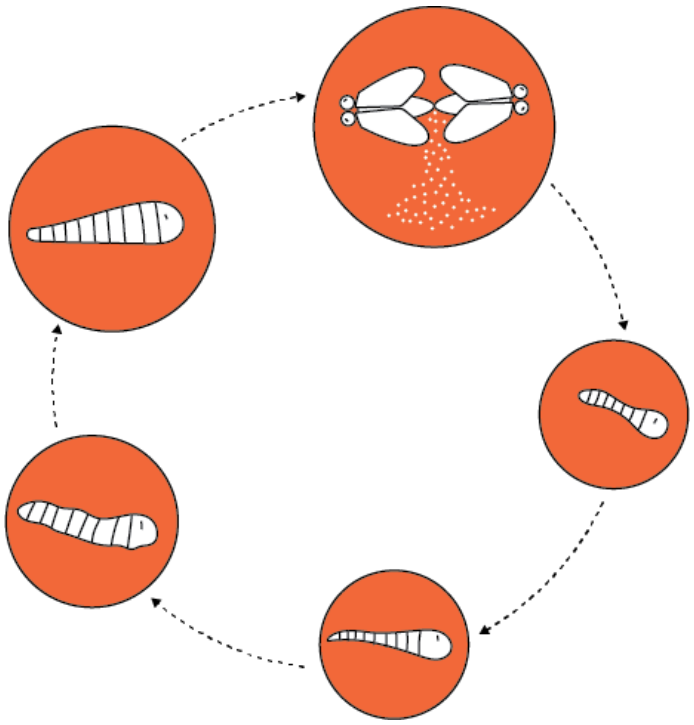
Black Soldier Flies Larvae (BSFL) are the best alternative for animal feeds as "fly larvae can convert low value organic materials into protein and fat."[55] In 1959, three researchers, Furman, Young, and Catts made the first contemporary studies about *Hermetia Illucens,* or Black Soldier Flies (BSF), and their larvae. [56] They come from the Stratiomyidae family, which is commonly found in tropical areas. "As adults, the BSF does not possess a stinger, nor do they

[52] "What Is Regenerative Design." *Regenerative Leadership Institute*, n.d.
[53] Huis, Arnold, Itterbeeck Joost, Klunder Harmke, Mertens Esther, Halloran Afton, Muir Giulia, and Vantomme Paul. n.d. "Edible Insects Future Prospect for Food and Feed Security." *Food and Agriculture Organization of the United Nation*.
[54] Arnold, Huis, Itterbeeck Joost, Klunder Harmke, Mertens Esther, Halloran Afton, Muir Giulia, and Vantomme Paul. n.d. "Edible Insects Future Prospect for Food and Feed Security." *Food and Agriculture Organization of the United Nation*.
[55] Gary, Burtle, Newton G.Larry, and Sheppard D.Craig. "Mass Production of Black Fly Pre Pupae for Aquaculture Diets." *University of Gorgia*
[56] R, . Rozkosný. *A Biosystematic Study of the European Stratiomyidae (Diptera)*. Vol. 2

possess a mouthpart or digestive organs to allow them to consume waste (BSF main energy source is the fat which remain from Larvae stage.); therefore, they do not bite either."[57] According to RIT Sustainability Department PhD candidate Shwe Sin Win, this is one of the reasons BSF typically die within in 5-8 days.

a. Life Cycle

Surendra, Olivier, Tomberlin, Rajesh, and Khanal Samir write that "The BSF lifecycle consists of four stages, namely: egg, larvae, pupae, and adult."[58] These different stages have varying significance for the Heart Brain Farm system.



I. Eggs

Female Black Soldier Flies find a mate a few days after they leave their last pupal case. The female discharges five hundred or more eggs in a dry environment. According to Diclaro II

[57] Haeree, Park. "Black Soldier Fly Larvae Manual." University of Massachusetts- Amherst

[58] K.C, Surendra, Olivier Robert, Tomberlin Jeffery K., Jha Rajesh, and Kumar Khanal Samir. "Bioconversion of Organic Wastes into Biodiesel and Animal Feed via Insect Farming." *Renewable Energy*

and Kaufman, every egg is roughly one millimeter in length, and is white and creamy. The female Black Soldier Fly produces her eggs close to organic matter.

II. Larvae

After the eggs have been discharged, according to the ESR International Research and Development Company (2008), they need to incubate for a period of one hundred and five hours. "Once the eggs hatch, the larvae find whatever waste they can and immediately start to consume it."[59] "Larvae are quite omnivorous, as they feed on a variety of materials ranging from animal and human feces, kitchen waste, to vertebrate remains (e.g., decomposing swine carcasses). Depending on the size of the larvae, type of the substrate available, and environmental conditions (e.g., moisture, temperature, and air supply), the larvae consume from 25 to 500 mg of organic matter per larva per day. Similarly, depending on the substrate type, the larvae are reported to reduce the waste by about 39% (pig manure) and 50% (chicken manure) to 68% (municipal organic waste) and have a food conversion ratio (FCR) of about 10 to 15 . The larval stage is usually 14 days or longer depending on availability of food , and appropriate environmental conditions ."[60] This pattern and versatility of consumption makes them ideal tools in the composting process for Heart Brain Farm.

III. Pupae

Surendra, Olivier, Tomberlin, Rajesh, and Khanal Samir write that "During the later larval stage; the stage prior to pupation termed as prepupae, larvae get rid of their digestive tract and migrate away from their food sources in search of dry and protected place to pupate. Since adults are non-feeding, BSF larvae consume organic matter as much as possible and store fat and

[59] Haeree, Park. "Black Soldier Fly Larvae Manual." University of Massachusetts- Amherst

[60] K.C, Surendra, Olivier Robert, Tomberlin Jeffery K., Jha Rajesh, and Kumar Khanal Samir. "Bioconversion of Organic Wastes into Biodiesel and Animal Feed via Insect Farming." *Renewable Energy*

protein in their body to support their metabolism during pupal and adult stages. By using a specially designed bioreactor, the typical migrating behavior of prepupae can be exploited for self-harvesting of pre-pupae for extracting fat and protein for value-added products generation. The pupation stage usually lasts for two weeks under ideal environmental conditions." [61] Then, the adult BSF emerges and begins reproducing again, thus repeating the life system cycle.

b. Environment Conditions and Temperature

Black Soldier Flies are very sensitive to the temperature of the environment in which they live. They are a tropical and warm-season species. The proper and suitable temperature for Black soldier flies and their life cycle stages is between 27-30 °C (80.6-86 °F). Based on the research of Jeffrey Tumberlin (2009), because of the sensitivity of Soldier Black flies, 3 °C can affect their development and their life span. He states in his conclusion that "For the black soldier fly, adults reared at 27C weigh 5% more and live roughly 10% longer than those reared at 30C. However, an average of 4 more d are required to complete larval development at 27C than at 30C. Because adults do not feed, other than to take water (Tomberlin et al. 2002), larval feeding is crucial to fitness . . ." (Tomberlin 932, 2009).[62]

Since Black Soldier Flies belong to tropical climates, breeding and maintaining these species requires additional energy in colder places. A study of this situation is currently being conducted by Shwe Sin Win at RIT. She plans to develop a breeding facility for Black Soldier Flies at RIT and to calculate the heat and energy which is generated by a colony of BSF and BSFL during the composting process. She writes that " In this project, we used bench experiments to analyze and determine the energy requirements for maintaining the colony

[61] K.C, Surendra, Olivier Robert, Tomberlin Jeffery K., Jha Rajesh, and Kumar Khanal Samir. "Bioconversion of Organic Wastes into Biodiesel and Animal Feed via Insect Farming." *Renewable Energy*

[62] Haeree, Park. "Black Soldier Fly Larvae Manual." University of Massachusetts- Amherst

through the winter, quantify the methane and CO_2 released from composting with BSFL, and calculate the value of the larvae and their wastes from an environmental perspective. Wastes and/or by-products including emissions were also be [*sic*] quantified."[63]

Humidity

Black Soldier Flies are not only sensitive to the temperatures of their environments, but are also affected by humidity during all phases of their lifespan. Low humidity can create a water loss for eggs, increasing the mortality rate. Moreover, with lower humidity, the adult's life span is shorter. However, as stated above, the flies require a dry place for pupation.

Lighting

Lighting is one of the fundamental elements of mating as Black Soldier Flies mate under direct light. According to Park, 85% of mating happens in the morning under direct natural sunlight. Under a 500-Watt quartz-iodine lamp the percent of mating reduces in comparison to natural light because the flies cannot properly see the waves coming from artificial light; therefore, they cannot produce mating behaviour. This is why higher wave light is recommended for conditions outside of a natural environment. In the end, circular systems thinking demands that the balance of energy waste and end-value must be quantified and accounted for.

c. Black Soldier Flies Larvae Economic Value

Black Soldier Fly Larvae reduces the cost of disposing of organic waste and turns it into a beneficial product for chicken, pig, and fish farmers. The cost is estimated to be 40-50% lower

[63] Shwe, Sin Win, and Piscitelli Alicia. "Quantifying the of Components of the Mass and Energy Balance of a Black Soldier Fly (BSF) Food Waste Composting System." Rochester Institute of Technology, n.d.

than that of other dried foods [Bullcok, 2013]. In addition to increased food value, larvae also generate biodiesel and biogas energy, which is a bonus positive impact. [64]

d. Ecosystem Value

Sin Win and Piscitelli write that "BSFL composting provides environmental benefits by reducing emissions and waste during the decomposition process, and because it can be conducted on-site, provides additional emission reduction by avoiding transportation. These advantages are achieved in the short-term and cumulative emission and waste reduction provide long-term benefits in relation to climate change. Some research suggests that diverting 1000 kg of food waste from landfills saves 900 kg of $CO2_{eq}$. Green and Popa recorded 5–6 times higher ammonium (NH4+) concentrations of organic leachate processed by BSF larvae than unprocessed leachate, suggesting further advantages in reducing emissions."[65]

Also, Black Soldier Fly larvae have significant nutritional values. "An analysis of dried Black Soldier Fly larvae (ESR International 2008) elucidates that it contains:

42.1% crude protein

34.8% ether extract (lipids)

14.6% ash

7.9% moisture

7.0% crude fiber

5.0% calcium

[64] Shwe, Sin Win, and Piscitelli Alicia. "Quantifying the of Components of the Mass and Energy Balance of a Black Soldier Fly (BSF) Food Waste Composting System." Rochester Institute of Technology, n.d.

[65] Shwe, Sin Win, and Piscitelli Alicia. "Quantifying the of Components of the Mass and Energy Balance of a Black Soldier Fly (BSF) Food Waste Composting System." Rochester Institute of Technology, n.d.

1.5% phosphorus

1.4% nitrogen free extract (NFE)"[66]

2. Redworms

Introduction

Mehdi and Ping write that "As key representatives of the soil fauna, earthworms are essential in maintaining soil fertility through their burrowing, ingestion and excretion activities. There are over 8000 described species worldwide, existing everywhere but in polar and arid climates."[67]

The earthworms work as a sensor to the ecosystem. "They are increasingly recognized as indicators of agroecosystem health and ecotoxicological sentinel species because they are constantly exposed to contaminants in soil."[68]

Eisenia fetida, well known as red wiggler or compost worm is a species of the earthworm family. In most countries, these worms are sold commercially for composting and to be used as fish bait. According to Jim Robbins, a writer in NY Times, Red Wigglers compost is commonly referred to as "black gold" for growers.[69]

[66] Haeree, Park. "Black Soldier Fly Larvae Manual." University of Massachusetts- Amherst

[67] Mehdi, Pirooznia, and Gong Ping. "Cloning, Analysis and Functional Annotation of Expressed Sequence Tags from the Earthworm Eisenia Fetida." *BMC Bioinformatics*, n.d.

[68] Mehdi, Pirooznia, and Gong Ping. "Cloning, Analysis and Functional Annotation of Expressed Sequence Tags from the Earthworm Eisenia Fetida." *BMC Bioinformatics*, n.d.

[69] Jim, Robbins. "Worms Produce Another Kind of Gold for Growers." *NYTimes*

a. Lifecycle

I. Anatomy

Red wigglers "have a lifespan of 4–5 years and are obligatorily amphimictic[70] even though each worm has both male and female reproductive organs"[71] which means they are hermaphroditic. Even though every worm contains one of the biological sexes, most of "Earthworms are generally considered to be cross-fertilization hermaphrodites."[72] Moisture helps them to breathe. If their skin becomes dry they will die.

II. Cocoon

Redworms, as hermaphrodites, possess both the male and female reproductive organs in one biological system. Redworm populations can increase every 60-90 days. "To copulate, two worms line up against one another facing opposite directions. In this position, both worms excrete so much mucous, that what is called a slime tube forms around their bodies. Each worm ejaculates sperm from its sex organs into this slime tube and it is then deposited in the other worm's sperm receptacle. The act of mating is completed, but the process of reproduction still continues as each worm goes its separate way."[73] All of the cocoons are in the shape of a drop, are much smaller than a grain of rice, and are yellow in color. After twenty-three days, the cocoon starts to change color, becoming a dark red. After three to four weeks the eggs hatch. The necessary temperature during the hatching of cocoons is 65-85 F degrees.

b. Redworms Ecosystem and Economic Value

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[70] "The union of the sperm and egg in sexual reproduction; sexual reproduction by the fusion of gametes from two organisms" (http://www.thefreedictionary.com/amphimictic).

[71] Mehdi, Pirooznia, and Gong Ping. "Cloning, Analysis and Functional Annotation of Expressed Sequence Tags from the Earthworm Eisenia Fetida." *BMC Bioinformatics*, n.d.

[72] Dar ıo, J. D ıaz Cos ın, Novo Marta, and Ferna ndez Rosa. *Reproduction of Earthworms: Sexual Selection and Parthenogenesis*,

[73] JOSH, Clark. "How Earthworms Work." *How Stuff Works Animals?*

"Earthworms have been called 'ecosystem engineers'."[74] As I mentioned before, redworms are a member of the earthworm family, and they also improve the quality and fertility of soil.

"The faeces of earthworm contain nitrate, calcium, magnesium, potassium and phosphorus which constitute an important component of the humus essential for plant growth."[75]

"Earthworms could be used to extract toxic heavy metals, including cadmium and lead, from solid waste from domestic refuse collection and waste from vegetable and flower markets, according to researchers writing in the *International Journal of Environment and Waste Management*."[76]

4. Practice, Process, Product

I needed to put my ideas related to the circular system and system thinking into action. It was time to test my ideas and implement them in my daily real life. This process would help me to evolve my methodology and ideas. This "Practice, Process, and Product" section is a discussion of my real life experiences during the development of this thesis project.

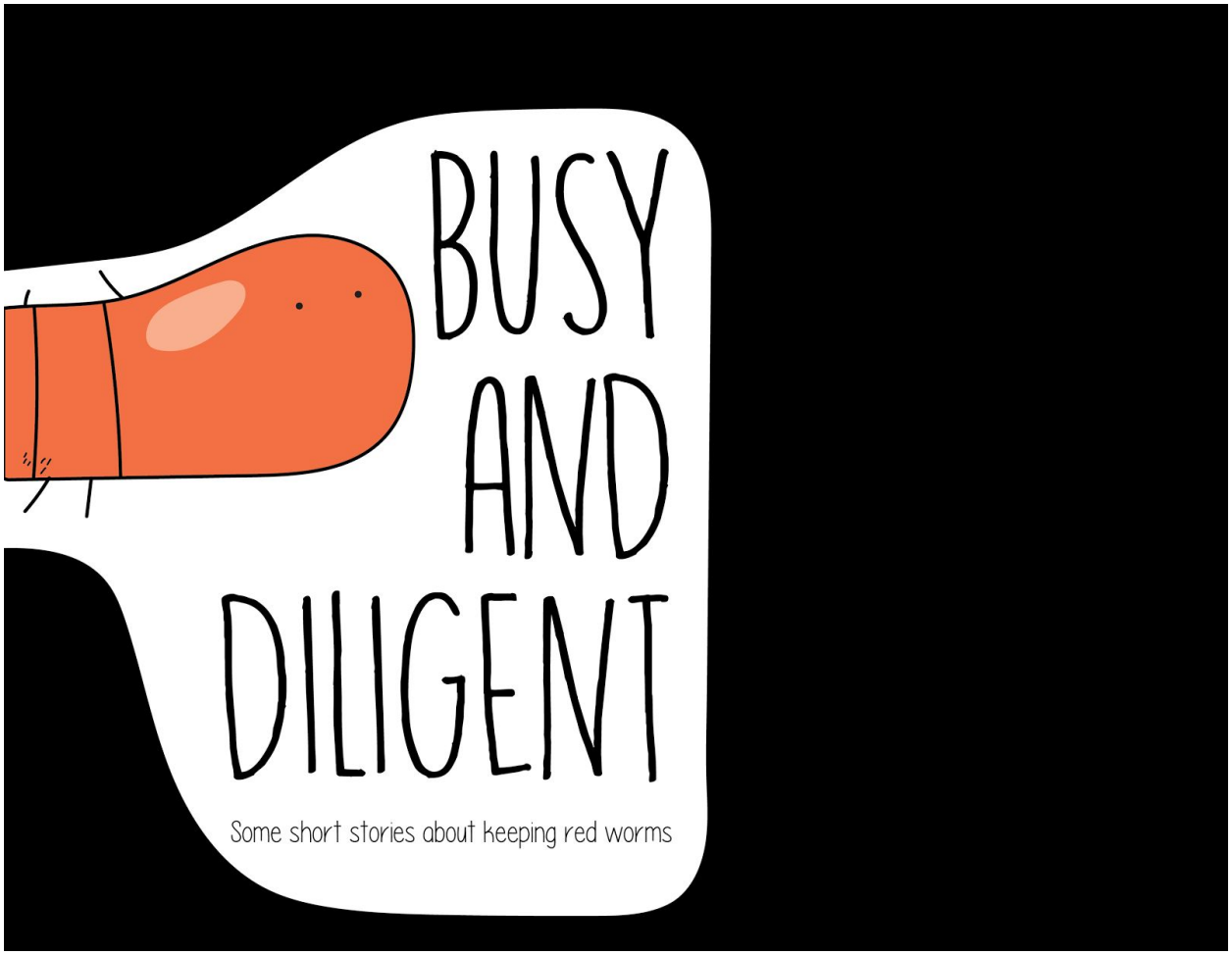
- **Diary of my red worm bucket**

To better understand the circular system and it's adoptability, I purchased Uncle Jim's Worm Farm 250 Count Red Wiggler Live Composting Worms on January 21st, 2016. To keep them in my kitchen I also purchased a large plastic bucket. My research focused on how I could keep these worms in the kitchen of my apartment. I was not thrilled to keep them in my tiny

[74] "Earthworm Society of Britain," n.d.
[75] Richa, Shah. "Economic Importance of Earthworm." *Biology Discussion*,
[76] "Earthworms Soak up Heavy Metal Bioremediation of Toxic Metals Using Worms." *Eurekalert, a Global Source for Science News*

apartment as I feared that they would escape from their bucket and be everywhere in my apartment: a nightmare scenario!

Some short stories about keeping red worms



Preparing the storage of redworms:

The bucket I purchased is quite large. I made about ten holes in its walls to allow air circulation, because food waste creates lots of methane gas and red worms need oxygen. I kept this bucket in the entrance of my kitchen near the main door, because I was concerned about the production of methane gas in my living space. I added some newspaper and paper tissues to the bucket and sprinkled some water on top. I thought that adjusting the living space from Uncle

Jim's Worm Farm to this new tiny bucket would be difficult for the red worms. At first, they did not go between the wet papers and instead began climbing the walls. This behavior was mentioned in the manual of Uncle Jim's Worm Farm. It took several days until they began to go between the wet papers. During these days, I opened the bucket's lid to give them some fresh air but it was not a pleasant picture. They were everywhere, even under the lid itself.

Leaving the community

I bought the red worms during the coldest days of winter. Despite this, some of them left their bucket community. When I found them lost in the middle of my kitchen floor, I grabbed them and put them back in their bucket.

During the summer, I moved to another house with a sun porch and I left the bucket there. During those hot days many worms again left the bucket. As the area out of the bucket was very hot, they typically dried up and died. I gave the dried worm chips to the birds (thus, they were still a part of a living system, even if the worm population inside the bucket was dwindling).

Next, I moved the worms to the basement of the house. The basement was very dark and humid. In a short time, most of the worms were out of the bucket, and I found them about a meter away. They thrive in dark and humid places.

Finally, I moved the bucket to the garden. All of the remaining worms soon escaped, never to be seen again, except three or four of them.

Attacked by others

Maintaining the proper PH inside the bucket is very important. Because my bucket was a fairly simple setup, and not controlled by LAB devices, I could not monitor the PH of the bucket. One day, when I opened the bucket to leave food scraps, realized that there were white little seeds everywhere. I thought at first that maybe they were the red worms' cocoons. I researched this and discovered that they were other creatures' seeds, which had entered the bucket vis food waste. The PH of the bucket was great for both the redworms and these new little white worms. In my research, I learned that it was time to change the PH. By squeezing a little lemon juice in the bucket I could destroy the white worms. Red worms also do not like acidic environments but they are stronger than white worms and are able to survive. I squeezed a half of lemon inside the bucket and two days later all the white worms appeared to be gone.

Did I kill one of them accidentally?

One day, after adding some kitchen waste to the bucket, I realized I had cut a worm in half by closing the lid. By this point, I had created emotional bonds with my worms and I started to cry when I saw the other half sticking outside of bucket. Nevertheless, I took both halves and put them back in the bucket. I researched this and learned that when you cut a worm in half, it does not die. The old folk story that cutting a worm in half with generate two worms is not true, but the head side can generate a new tail and continue living.

My mom meets the worms

Three months after I started keeping red worms in my kitchen, my mom visited me from Iran. During these months leading up to her visit, I had regularly talked about my little worms in the kitchen and how I really like the way they work. I mentioned that I even gave them names,

which had lead my mother to believe that I had lost my mind. During her first week here, she did not want to see or in any way interact with them. Eventually, however, she started to give her food leftovers to them as I did. Then she really become excited about them and she started to tell her friends in Iran and Turkey about how they reduce the amount of garbage we generate while turning our organic waste into something useful and valuable. She really liked the idea of keeping the food's value in every step.

Organic compost turned to food after five months

While I was keeping red worms in my apartment, I planted some vegetables in my design studio at RIT. I bought grow lights to keep them alive during the cold and dark winter in Rochester. They grew but never yielded any food. When the summer came, the compost in my kitchen was ready to be emptied. E Shwe Sin Win, a PhD candidate in RIT's Sustainability Department helped me to prepare a plot in RIT's community garden. There, I planted all of the vegetables from winter. The community garden plot I had was very dry and chunky from years of disuse. I added my 5 months compost to this garden. My plants started to die, but E Shwe Sin Win brought me some cow manure which helped me to save them. The plants eventually gave me lots of vegetables (including: squash, pepper, tomatoes, beets, and parsley), some of which was given to local homeless shelters.

My daily practice changed

Today's date is November 11, 2016, a full eleven months after I first bought red worms. Many of my worms have become food for other species, most of them of them have been lost

due to containment challenges, but I learned a lot during the process. Now, I cannot toss my food waste to the regular garbage. I keep it and place it in the bucket in the garden. My norms and routines related with food have changed. I tell these stories to everyone as I try to reach as broad of an audience as possible to create change in the food practices of our daily lives.

- **Field Survey**

I made a trip to a red worm farm called WORM POWER, in Geneseo, New York, to learn about how farms like this work. Ted Miller gave me a tour of the farm. He started the tour by explaining the raw materials they use in their facility for red worm compost. He mentioned that the annual waste of cow manure in the farm close to their facility is roughly the same amount as the annual waste produced by Brighton, NY (a town of about 35,000 people). WORM POWER uses three different materials in the first phase of compost making. Cow manure, which they buy from their neighboring farm, corn plant leftovers, and the worm compost. Miller stated that the worm compost behaves similarly to yeast in bread. They mix these three materials together and leave them in big reservoirs. They add air and heat for a couple of months to get rid of methane gas and bacteria. Then they give this mix to redworms to process it. The nutrient content amount in the mix before the redworms process it is about half of what it is afterwards. The process produces a consistently high quality soil product that is very important for the farm's sales.

I highlighted some "Aha!" moments during this trip:

1) There is no circular system in this production cycle.

2) During our conversation about the three materials that are mixed, Miller mentioned corn. Corn, again, is in the picture of American's food cycle - here as an ingredient in organic compost. I asked Miller if the farm's organic compost was used to grow this corn. He stated that their organic compost was prohibitively expensive for most farmers (the farm's clientele is typically comprised of golf clubs and organic berry farms). For growing corn, instead, WORM POWER uses chemical fertilizers. This means that they add chemicals to the soil in order to produce corn so that it can be turned it to organic fertilizer.
3) Miller also stated that they send their fertilizer to places as far from Geneseo, NY as Los Angeles and Seattle. He said that organic fertilizer is expensive and that the added transportation costs further increase the price. However, many organic producers are able to absorb such costs as the organic food that they sell is also quite pricy.
4) At one point, local Wegmans grocery locations offered their food waste to WORM POWER so that it could be composted. The facility did not accept it for two reasons: Firstly, different fruits and vegetables in different seasons yield different results in the final compost that is produced. The lack of consistency in the farm's product would be an obstacle to their ability to their sales approach. Secondly, a special permit from a waste management institution would be necessary in order for the farm to process Wegmans' food waste, a very long process that the farm did not want to go through.

- **How to Change a Community's Collective Behavior**

One of the major challenges in this project is changing people's behavior, routines, and norms. Linear systems and linear thinking have penetrated almost every part of modern Western life. Linear systems introduced convenience (consumption and freedom of choice) culture, which generates enormous amounts of waste and ruins our natural resources. Drawing from the theory of change, new and more sustainable approaches can be used to improve human behavior.

The system of change has several different levels: personal, social, and political. My plan is first to shift the individual's practice. After that, social change will follow, as behavioral change is contagious. The behavioral changes of individuals and communities will change demands, ultimately forcing companies and distributors to respond.

I use different methodologies to address this challenge: 1) I use the Consequence Model of creating change (Heath and Heath 2010, 153). This approach means that if people know about the benefits of change, they will gain satisfaction through the pursuit of change in their lives. 2) I also draw upon Gamification and Game Theory methodologies (Acaroglu 2016). By developing a smartphone application, people can be encouraged to play with their kitchen waste as a way to maximize the effectiveness of their participation and to enhance the experiences of the wider community. Gamification creates motivation, enhances pleasure, and increases success, and at the end of the game individuals (and the wider community) will be rewarded with a discount on healthy foods. 3) I lastly apply Slow Education to the educational toolkit I am designing with two different target groups: First, the toolkit helps designers to apply a circular economy approach during their design thinking process in order to maximize the value of the materials and resources that they use, and also to encourage them to think about the bigger system rather than just the individual products. Second, the toolkit helps families to adopt the circular system in

their daily lives to minimize their carbon/slave/waste footprints. Slow Education will help to educate both the community and designers and to lead them to deeper learning.

5. Conclusion

This project is a practice to apply circular economy and systems thinking to the design thinking process. We are living in a set of complex systems which are interconnected with one another. We cannot ignore these related components that work and function together. Designing to address this complex arena, which includes problems such as: food systems, water systems, politics, refugee problems, and more, needs to combine systems thinking, sustainability, and sociological awareness. Participation and collaboration between different members within communities will be necessary to bring about meaningful change.

I have published some of the ideas I discuss in this thesis on social media. The informal feedback I received from people suggests that they are eager to learn more about circular economy and system thinking. The new cohort of entrepreneurs and business-starters is more aware of the importance of circular system thinking than their predecessors. Unfortunately, our education (at any stage of our lives) does not address this topic sufficiently. As a huge gap exists in our educational system related with system thinking and circular system we need to create and encourage this positive change.

I recently started a new program called Heart Brain Kid and I am collaborating with scientists, educators, and designers to design a “play-book” for parents to interact with their kids and to practice system thinking and circular economy in their daily lives.

Here are some brief steps for adapting circular systems thinking to the design process:

- Understand the bigger picture: See both the parts and the whole. Considering their

dynamics is necessary for finding innovative solutions addressing the whole system.

- See the interconnected elements: Seeing the interconnections of elements increases awareness of networks between them. This can explain how even a seemingly small action can potentially have huge consequences.

- Identify relationships: Understanding that interconnections can be infinite and that their dynamics are nonlinear allows multi-direction perspectives to emerge for solving complex problems.

- Understand the function as a whole: According to Peter Senge, author of *The fifth discipline,* "Today's problems are often yesterday's solution." As a designer (and as a human), I need to understand that every solution I create to answer a specific need can potentially create another problem in another part of system. A better understanding of the function as a whole will help to limit the negative consequences, yielding net benefits to the system as a whole.

- Understand the dynamics of the elements, both separately and together: Everything around us is made up of complex systems which contain sets of elements working together to create holistic functions. If we want to solve any problem we must consider how it is a part of this complex system. We need to consider all the players, elements, connections, and their dynamic relationships with one another.

By raising awareness of the circular system mindset in our communities, we can begin helping them to accept, and even help design, ways in which to put these values and practices into action.

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